**The Super Ginormous Covalent Bonding Packet**

**(Chapter 9)**

Within this packet you will find all that you need to know about covalent bonding and a large amount of practice opportunities. You will not be able to understand the rest of the year of chemistry if you do not understand bonding. Thus it is important that you are able to adequately complete this packet, no matter how grueling it may seem.

**A Covalent Bond**

A covalent bond forms between nonmetals and other nonmetals. Some of the valence electrons are shared between the two or more nonmetal atoms. This sharing creates a covalent bond and accomplishes a noble gas configuration (octet) for each atom involved.

Hydrogen is a nonmetal

Metals

Nonmetals

Covalent bonds come in two varieties; nonpolar and polar. The polarity of the covalent compounds are caused by differences in the electronegativity of the different elements involved. Polarity will be discussed later. Because there are multiple types of covalent bonds, the compounds they form range from weak bonds to strong bonds. Some have really low melting and boiling points, and some have really high ones. Covalent compounds can be somewhat soft and brittle (like the graphite in your pencil) or very, very hard (like a diamond). Regardless of the type of covalent bond, all covalently bonded atoms form a **molecule**.

Note: both ionic bonds and covalent bonds make a **compound**, but only compounds with covalent bonds can be called a **molecule**.

**Forming a Covalent Bond**

Nonmetals share valence electrons with other nonmetals in order to get the full octet. This means there are no actual positive and negative charges on the individual atoms. Unfortunately, the nonmetals usually can share many different amounts of valence electrons. Thus, if you were to make a compound with nitrogen and oxygen it could be NO, NO2, N2O, N2O3, N2O4, or N2O5.

**Naming and Writing Covalent Molecules**

Because there is no guarantee about how exactly two nonmetals will form a molecule, a different method needs to be used when naming and writing formulas than was used with ionic compounds.

When given the formula for a molecule, the name needs to indicate the number of each atom, because there are no charges to balance. In order to accomplish this, prefixes are added to the name of each element stating how many of that element there are in that particular compound. You will want to memorize these first ten prefixes:

Mono = 1 Tetra = 4 Hepta = 7 Deca = 10

Di = 2 Penta = 5 Octa = 8

Tri = 3 Hexa = 6 Nona = 9

There are a few details to note:

1. If the *first* element has a subscript of only 1, do not write the mono in the front.
2. When using the prefix mono with oxygen, drop one of the two “o”s. Thus it is “monoxide”, not “monooxide”.
3. The ending of the compound still is “ide”.

**Examples:** NO = Nitrogen Monoxide

NO2 = Nitrogen Dioxide

N2O = Dinitrogen Monoxide

N2O3 = Dinitrogen Trioxide

N2O4 = Dinitrogen Tetraoxide

N2O5 = Dinitrogen Pentaoxide

**Exercise 1**:

Write the name of each of the following molecular compounds. The number of the subscript becomes the amount of the prefix.

Remember:

1. If the *first* element has a subscript of only 1, do not write the mono in the front.
2. When using the prefix mono with oxygen, drop one of the two “o”s.
3. The ending of the compound still is “ide”.

1. OF2 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. Cl2O8 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3. SO3  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4. P4O10 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

5. CO \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

6. CH2 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

7. N2H4 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

8. ClO3 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

9. CCl4 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

10. H2S \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

11. N2O5 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

12. P4S3 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

13. SO2 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

14. S2F10 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

15. SF6 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

When writing the formulas for named molecules, there is no need to worry about criss-crossing charges as the prefixes already state how many of each element there is in the molecule. Simply turn the prefixes into subscripts.

Exercise 2:

Write the formulas for the following named molecules. Do not write subscripts of 1.

1. Carbon Tetrabromide \_\_\_\_\_\_\_\_\_\_\_\_ 2. Dichlorine Heptaoxide \_\_\_\_\_\_\_\_\_\_\_\_

3. Dinitrogen Pentaoxide \_\_\_\_\_\_\_\_\_\_\_\_ 4. Boron Trichloride \_\_\_\_\_\_\_\_\_\_\_\_

5. Dinitrogen Tetrahydride \_\_\_\_\_\_\_\_\_\_\_\_ 6. Diphosphorus Trioxide ­\_\_\_\_\_\_\_\_\_\_\_\_

7. Carbon Disulfide \_\_\_\_\_\_\_\_\_\_\_\_ 8. Dinitrogen Tetraoxide \_\_\_\_\_\_\_\_\_\_\_\_

9. Phosphorus Pentachloride \_\_\_\_\_\_\_\_\_\_\_ 10. Nitrogen Trifluoride \_\_\_\_\_\_\_\_\_\_\_\_

11. Disulfur Dichloride \_\_\_\_\_\_\_\_\_\_\_\_ 12. Dichlorine Trioxide \_\_\_\_\_\_\_\_\_\_\_\_

13. Nitrogen Triiodide \_\_\_\_\_\_\_\_\_\_\_\_ 14. Boron Trifluoride \_\_\_\_\_\_\_\_\_\_\_\_

15. Sulfur Hexafluoride \_\_\_\_\_\_\_\_\_\_\_\_ 16. Phosphorus Pentachloride \_\_\_\_\_\_\_\_\_\_\_

**Acids**

Acids are special molecules that when dissolved in water will produce an H+ ion as it breaks apart. For example, HCl dissolves in water to form H+ and Cl- ions. This makes HCl an acid when dissolved in water, otherwise as a solid it is just hydrogen chloride.

There are two major types of acids, those with oxygen and those without. If the acid does NOT have oxygen in the formula, then it’s called a *binary acid*. If the acid does have oxygen in the formula, then it’s called an *oxyacid*.

**Binary Acids**

Binary acids contain hydrogen and only one other element, however there may be more than one of the hydrogen. It is still going to be necessary to balance out the negative charges of the nonmetal with enough hydrogens to form a neutral (zero charge) compound. Thus the criss-cross method will still be used.

**Exercise 3:**

1. Write the charge for each of the following nonmetals.

2. Criss-cross the following with enough hydrogens to form a neutral compound. Write the formula in the box. Do not write subscripts of 1 or “+” and “-“ charges.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **N** | **F** | **P** | **S** |
| **H+** | **1** | **2** | **3** | **4** |
|  | **Cl** | **Se** | **Br** | **I** |
| **H+** | **5** | **6** | **7** | **8** |

There is a special form that is used to name a binary acid:

“Hydro\_\_\_\_\_\_\_\_\_ic Acid”

All acids will end with the word “Acid”. The blank in the above form is filled in with the root of the element that the hydrogen is bonded to. All the possible roots are:

Bromine = brom Iodine = iod Selenium = selen

Chlorine = chlor Nitrogen = nitr Sulfur = sulfur

Fluorine = fluor Phosphorus = phosphor

**Exercise 4:**

For each of the molecules made in exercise 3, write the name of the molecule as if it was an acid.

1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

5. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

6. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

7. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

8. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Oxyacids**

Oxyacids must have hydrogen to be considered an acid, and must have oxygen to be considered an oxyacid, and there still must be a third element present to hold it all together. Thus an oxyacid has three elements. Basically this makes oxyacids look like polyatomic ions bonded to hydrogens. Also, for the purposes of naming the acid the name of the polyatomic ion is needed, so here’s a review of different polyatomic ions, their names, and charges. You will note that only those polyatomic ions with oxygen are needed in our current list.

C2H3O2 - Acetate NO2 - Nitrite

AsO4 -3  Arsenate C2O4 -2 Oxalate

AsO3 -3 Arsenite ClO4 - Perchlorate

BO3 -3 Borate MnO4 - Permanganate

CO3 -2 Carbonate PO4 -3 Phosphate

ClO3 - Chlorate PO3 -3 Phosphite

ClO2 - Chlorite SiO3 -2 Silicate

CrO4 -2 Chromate SO4 -2 Sulfate

CNO - Cyanate SO3 -2 Sulfite

Cr2O7 -2 Dichromate S2O3 -2 Thiosulfate

ClO- Hypochlorite

NO3 - Nitrate

Helpful Note:

If you group all the polyatomic ions of chlorine and oxygen, a pattern will form:

ClO- Hypochlorite

ClO2 - Chlorite

ClO3 - Chlorate

ClO4 - Perchlorate

“Hypo” means “lacking”, so *hypo*chlorite has the lowest amount of oxygens, and Per comes from “hyper” which means “excessive”, so *per*chlorate has the most oxygen. This pattern also follows for the rest of the Halogens.

**Exercise 5:**

Write in the names for the other halogen-oxygen polyatomic ions. Use the pattern shown above.

1. FO- \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 9. IO- \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. FO2- \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 10. IO2- \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3. FO3- \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 11. IO3- \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4. FO4- \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 12. IO4- \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

5. BrO- \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

6. BrO2- \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

7. BrO3- \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

8. BrO4- \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Like with the binary acids, oxyacids need enough hydrogens to balance out the charge on the polyatomic ion part. Thus once again it is necessary to criss-cross to form the compounds.

**Exercise 6:**

Criss-cross the following polyatomic ions with hydrogen and write the compound in the space. It will not be necessary to use parentheses or reduce.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **AsO3 -3** | **BO3 -3** | **ClO2 -** | **CrO4 -2** | **Cr2O7 -2** | **ClO-** |
| **H+** | 1 | 2 | 3 | 4 | 5 | 6 |
|  | **C2O4 -2** | **MnO4 -** | **PO3 -3** | **SO3 -2** | **S2O3 -2** | **IO4-** |
| **H+** | 7 | 8 | 9 | 10 | 11 | 12 |

When naming oxyacids a name change is necessary. The hydrogen is not mentioned because it obviously needs to be there for the molecule to be an acid. If the polyatomic ion ends in “ite”, then those letters are changed to “ous” for the name of the oxyacid. If the polyatomic ion ends in “ate”, then those letters are changed to “ic” for the name of the oxyacid. Often a little saying is suggested for remembering this change:

I ate it and it was ic-ky

The pneumonic is a reminder that “ate” turns to “ic”, and then by default “ite” turns to “ous”. Once the name has been changed, the word “acid” is still added to the end.

Examples:

HC2H3O2 HNO2

As a solid: Hydrogen Acetate As a solid: Hydrogen Nitrite

As an acid: Acetic Acid As an acid: Nitrous Acid

So “ate” get replaced with “ic” and “ite” gets replaced with “ous”, the hydrogen does not get named, and the word “acid” is added.

**Exercise 7:**

Name the molecules from exercise 6 as acids. Change the endings and add the word acid as necessary.

1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

5. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

6. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

7. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

8. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

9. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

10. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

11. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

12. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

When writing the formulas for acids, the clue that it is an acid is the word “acid” on the end.

1. Determine if it is a binary acid or an oxyacid.

2. Determine which elements or polyatomic ions are involved.

3. Criss-cross so that there are enough hydrogens to balance out the charge on the second part of the acid.

**Exercise 8:**

Write the formulas for the following acids. Follow the steps above.

1. Arsenic Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 2. Sulfuric Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3. Perchloric Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 4. Hydrobromic Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

5. Hydronitric Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 6. Cyanic Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

7. Silicic Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 8. Phosphoric Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

9. Hydroselenic Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 10. Hydrosulfuric Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

11. Nitric Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 12. Hypoiodous Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

13. Bromous Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 14. Hydrophosphoric Acid \_\_\_\_\_\_\_\_\_\_\_\_

15. Fluorous Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 16. Chloric Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

17. Carbonic Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 18. Perbromic Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

19. Hypobromous Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_ 20. Perfluoric Acid \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Molecular Structures**

**(Lewis Structures)**

With the understanding of how atoms bond covalently (and how many of each atom is involved), it is possible to consider how the bonded molecule would look, if it was big enough to see. In order to show this on paper, a structural formula is written. A structural formula not only has the normal formula, but shows how the atoms are arranged around the central atom. Lewis structures are a particular type of structural formula with certain symbols:

A line between elements show a *bond*, like H – N – H, a bond is 2 electrons

|

H

**..**

A pair of dots shows a *lone pair*, like H – N – H, a lone pair is 2 electrons

‌‌‌‌‌ |

H

Most nonmetals are wanting to get a total of 8 electrons, so in the above example nitrogen has 8 electrons (3 bonds = 6 electrons, 1 lone pair = 2 electrons; a total of 8 electrons.)

There is a simple method that can be used to determine how many bonds and how many lone pairs should be around each atom. This method is the W-A-S method.

**W** = the total number of electrons all the atoms *want*

(each atoms wants 8, but hydrogen only wants 2)

**A** = the total number of electrons all atoms have *available*

(count the dots off the periodic table)

**S** = the total number of electrons that need to be *shared*

(divide by 2 for the number of bonds)

If this method is followed for NH3

W = 8 (for N) + 2 (for H) + 2 (for H) + 2 (for H) = 14

A = 5 (for N) + 1 (for H) + 1 (for H) + 1 (for H) = 8

Subtract A from W (it should never be negative)

W – A = 14 – 8 = 6

S = 6 divide by 2 to find 3 bonds needed…

Thus NH3 looks like H – N – H

‌‌|

H

But it’s not done…

Each hydrogen only wants 2 electrons, and a bond already counts as 2, so each hydrogen is full. But nitrogen wants 8, and three bonds only gives it 6, so it is necessary to add another pair of electrons…

Added lone pair

**..**

H – N – H

|

H

Notice that the single N is in the middle with the three H around the outside. H will *always* be around the outside, and the element with just one of the element in the molecule will *always* be in the middle (molecules like to be as symmetrical as possible.)

Try this:

Write the lewis structure for NBr3

Start with W-A-S

W = 8 (for N) + 8 (for Br) + 8 (for Br) + 8 (for Br) = 32

A = 5 (for N) + 7 (for Br) + 7 (for Br) + 7 (for Br) = 26

S = 32 – 26 = 6, divide by 2 to find 3 bonds necessary

Br – N – Br

|

Br

But it’s not finished…

Once again nitrogen needs two more electrons to have 8, so 1 lone pair is needed

**..**

Br – N – Br

|

Br

But it’s still not finished…

Each Br wants 8, but only has 1 bond, this means each Br needs 3 more lone pairs

**..** **.. ..**

**:**

**:**

Br – N – Br

**..**

**..**

|

**:**

**:**

Br

**..**

Finally with 3 bonds and a total of 10 lone pairs, the lewis structure for NBr3 is finished.

Helpful hints:

1. Be symmetrical as much as possible
2. The element with only 1 atom is in the middle, and hydrogen is always on the outside.
3. All elements on the outside get a total of 8 electrons (usually 1 bond and 3 lone pairs), but hydrogen only gets 1 bond.

**Exercise 9:**

For each of the following molecules, fill in the W-A-S, and then draw the lewis structure in the box.

1. PH3

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

2. CCl4

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

3. OF2

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

4. NI3

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

5. SiCl4

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

6. SeI2

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

7. OH2

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

**Molecules with Charges**

Sometimes a molecule will have more or less electrons than normal. This causes the entire molecule to have a charge. Remember a “+” charge means there are less electrons than usual, and a “-“ charge means more electrons than usual.

When a molecule has an overall charge, two things happen:

1. The A gets adjusted for the charge (subtract for a + charge, add for a – charge)
2. The entire molecule gets put into brackets with the charge shown outside

Example:

AsO4-3

[ ]

**..**

O

**..** |  **..**

O – As – O

|

O

W = 8+8+8+8+8 = 40

-3

**:**

**:**

A = 5+6+6+6+6 *+3* = 32

**..**

**..**

**:**

**:**

S = 8

**..**

**:**

**:**

# bonds = 4

**Exercise 10:**

For each of the following molecules, fill in the W-A-S, and then draw the lewis structure in the box. *Don’t forget to add to the A for – charges and subtract for + charges. Use brackets.*

1. AsO3-3

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

2. AtO4-

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

3. ClO4-

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

4. BF4-

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

5. ClO2-

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

6. PO3-3

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

7. HSO3-

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

8. NH4+

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

Molecules with Multiple Bonds and Resonance

Sometimes a molecule with only three outside atoms may need to make four bonds. Or maybe it has only 2 outside atoms and needs to make 3 or four bonds. In this situation the bonds can double or triple up between atoms to make a multiple bond.

Examples:

**..**

**..**

CO2 N2

O = C = O :N ≡ N:

**..**

**..**

Notice that the multiple bonds still give all elements involved a total of 8 electrons. It will be necessary to have a multiple bond anytime the number of bonds is bigger than the number of outside atoms. Hydrogen can NEVER have a multiple bond.

Often multiple bonds are not needed in a symmetrical fashion as shown above. Perhaps out of three bonds only one needs to be a multiple bond…

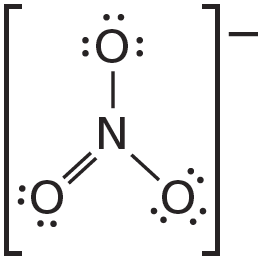
For example, NO3-

W = 32

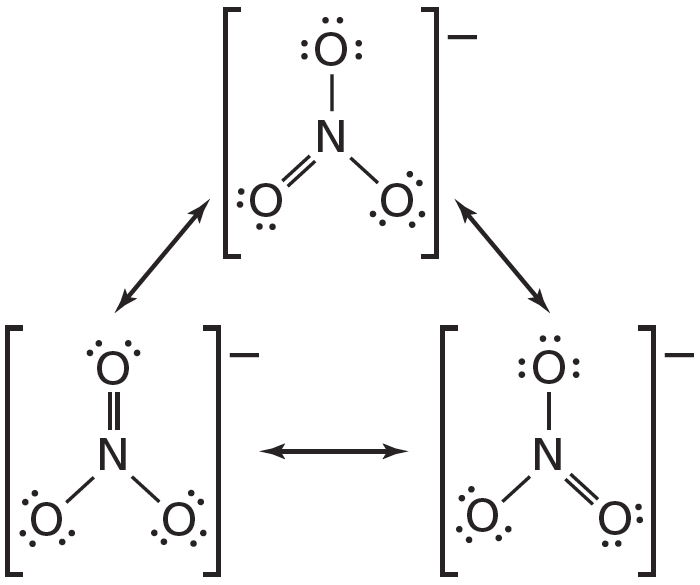
A = 24

S = 8

# bonds = 4 – but there is only 3 outside oxygen atoms…

 So use a double bond

Notice each oxygen still has 8 electrons; two of the oxygens have 1 bond and 3 lone pairs, and 1 oxygen has a double bond (counts as 4 electrons) and only two lone pairs. There is nothing special about the oxygen on the left that it must get the double bond, so there are two other possibilities – the oxygen on the top could have the double bond, and the oxygen on the right could have the double bond. In total there are three different structural drawing that can be made. These three are called resonance structures, and all the possibilities must be shown.



The double ended arrow separates and indicates the drawings are resonance structures.

**Exercise 11:**

For each of the following molecules, fill in the W-A-S, and then draw the all possible resonance structures in the boxes. *Don’t forget to add to the A for – charges and subtract for + charges. Use brackets.*

1. SO3

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

2. SO2

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

3. NO2-

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

4. CO3-2

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

5. HCO2-

W = \_\_\_\_\_\_\_\_\_\_

A = \_\_\_\_\_\_\_\_\_\_

S = \_\_\_\_\_\_\_\_\_\_\_

# bonds = \_\_\_\_\_\_

**3 Dimensional Shapes (VSEPR, Hybridization, and Polarity)**

It is now time to consider the actual orientation of our molecules in real-life, three-dimensional space. The method for figuring out where the atoms go is called the Valence Shell Electron Pair Repulsion theory (VSEPR for short). Once the 3-D arrangement is known, it is easy to find the hybridization and the polarity.

**Finding VSEPR shape**

The method used to find the VSEPR shape involves finding the number of bonds and the number of lone pairs on the central atom. Then it will be matched to a list (presented later in this packet) to determine the shape, the hybridization, and the polarity.

1. Determine the W-A-S.
2. Determine the total number of *electrons pairs* (EP) in the molecule = A/2
3. Determine the number of *bonding pairs* (BP) in the molecule = Total # of atoms -1
4. Determine the number of central pairs (CP) = EP – (3 x BP, except for H use 0)

…each outside atom has 3 lone pairs

… hydrogen has no lone pairs, counts as zero

1. Determine the number of lone pairs (LP) on the central atom = CP – BP (never negative)

Once the EP, BP, CP, and LP have been determined, the rest of the information can be looked up in this chart:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **C.P.** (number of electron pairs) | **L.P.** (number of lone pairs on central atom) | **E.G**.  (electron geometry) | **M.G**. (molecular geometry) and picture | **Hybridization** | **Usual**  **Polarity** |
| 2 | 0 | Linear | Linear  linear | sp | nonpolar |
| 3 | 0 | Trigonal Planar | trigonal planarTrigonal Planar | sp2 | nonpolar |
| 3 | 1 | Trigonal Planar | Angular (bent)  angular | sp2 | polar |
| 4 | 0 | Tetrahedral | Tetrahedral  tetrahedral | sp3 | nonpolar |
| 4 | 1 | Tetrahedral | Trigonal Pyramidal  trigonal pyramidal | sp3 | polar |
| 4 | 2 | Tetrahedral | Angular (bent)  angular2 | sp3 | polar |
| 5 | 0 | Trigonal Bipyramidal | trigonal bipyramidalTrigonal Bipyramidal | sp3d | nonpolar |
| 5 | 1 | Trigonal Bipyramidal | Irregular Tetrahedral  irregular tetrahedral | sp3d | polar |
| 5 | 2 | Trigonal Bipyramidal | T-Shaped  T-shaped | sp3d | polar |
| 5 | 3 | Trigonal Bipyramidal | Linear  linear2 | sp3d | polar |
| 6 | 0 | Octahedral | Octahedral  octahedral | sp3d2 | nonpolar |
| 6 | 1 | Octahedral | Square Pyramidal  square pyramidal | sp3d2 | polar |
| 6 | 2 | Octahedral | Square Planar  square planar | sp3d2 | nonpolar |

With the above chart and the EP-BP-CP-LP determination, it is now possible to even handle exceptions to the W-A-S method.

For example: XeF4

W = 40

A = 36

S = 4

# bonds = 2 *– obviously this doesn’t work*

Now do EP-BP-CP-LP (see page 20)

EP = A/2 = 18

BP = 5 atoms – 1 = 4 *- this says 4 bonds total*

CP = 18 – (4 outside atoms x3 each) = 6

LP = 6 – 4 = 2 *- this says 2 lone pairs on the central atom*

Look at the chart on page 21. XeF4 has a CP of 6 and LP of 2, so its electron geometry is *octahedral*, and its molecular geometry *is square planar*. To draw it, it would look like:

**..**

**:**F

**..**

F**:**

**..**

‌‌‌|

Xe

|

**..**

**..**

**..**

**:**F

**..**

F**:**

**..**

**..**

**..**

Also, the chart states that it is sp3d2 hybridized and nonpolar. The hybridization states which orbitals are involved in the bonding of the molecule, and the polarity states if the molecule will act like a little magnet (having positively and negatively charged ends).

***If the molecule has more than just two types of elements, it will be be polar, even if the chart says nonpolar.***

**Exercise 12:**

For each of the following molecules

1. Determine W-A-S and # of bonds.
2. Determine EP-BP-CP-LP
3. Create an appropriate drawing using the chart on page 21. If there is a charge, don’t forget the brackets, and if there are resonance structures, draw all the possible structures.
4. State the hybrization and the polarity.

1. NH3

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_

2. CF4

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_

3. PF5

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_

4. H2O

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_

5. BF3

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_

6. SeF6

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_

7. ClO4-

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_

8. H2Se

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_

9. AsF3

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_

10. GaI3

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_

11. PH4+

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_

12. CO3-2

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_

13. XeF4

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_

14. CO2 (two multiple bonds)

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_

15. ICl3

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_

16. HCCl3

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_

17. BrF3

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_

18. ClF5

W = \_\_\_\_\_ EP = \_\_\_\_\_

A = \_\_\_\_\_ BP = \_\_\_\_\_

S = \_\_\_\_\_\_ CP = \_\_\_\_\_

# bonds = \_\_\_\_\_\_ LP = \_\_\_\_\_

Hybrization = \_\_\_\_\_\_\_\_\_\_ Polarity = \_\_\_\_\_\_\_\_\_\_